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by

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INTRODUCTION

The simple heat balance described in this report gives perspective to the importance of the various sub-processes in the cupola smelting of Peace River iron ore.

In the process briquets of iron ore containing sufficient carbon (char) to reduce the ore to metal are smelted in a cupola, the coke bed of which supplies all the necessary heat. Table 1 gives the composition of the briquets used in experimental smelting trials. It should be noted that 6% lime is included in the briquet and this lessens the thermal load on the furnace for calcining limestone, which is also used to bring the slag basicity to 0.6. Lime was included in the briquet to aid initial fluxing, but this has not been proved to be necessary.

Mass Balance

Balance basis 1 ton hot iron

Slag weight from chemical analysis 2872.8 lbs of gangue/ton Fe are present in briquets.

Let C = carbon (in coke) required in lbs, assume coke has 10% ash and ash is all acid.

From chemical analysis 346.5 lbs of CaO from added limestone are required to make briquet gangue of 0.6 basicity.

Total slag weight is then $2872.8 + 0.1C + 346.5 + 0.06C = 3219.3 + 0.16C$

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TABLE 1

	% Fe	% SiO_2	% Al_2O_3	% CaO	% MgO
Ore	23.26	12.92	3.75	1.26	.73
Char	-	.25	.19	.23	.09
Lime	-	.07	.06	4.38	.05
Total	23.26	13.23	4.00	5.87	.87
After curing 100 lbs of green briquets weigh 87.5 lbs and contain					
	26.56	15.12	4.56	6.70	.99

Briquets contain 73% ore, 11% char, 10% asphalt, 6% lime.

A. Heat Out

1. Reaction

The carbon requirement to reduce the ore is not a fixed quantity, depending carbon type, particle size, etc. Requirements for similar briquets depend on thermal history during reduction, but laboratory data suggests the following equation is approximately followed:

$$2\ Fe_2O_3 + 5C \rightarrow 4CO + CO_2 + 4\ FE$$

Assuming all iron in ore is Fe^{3+} thermal requirement is

$$3.106 \times 10^6 \text{ Btu}$$

(If CO is only gas evolved from briquet thermal requirement would increase to 3.768×10^6 Btu.)

2. Sensible Heat in Iron and Slag

Assume tapping temperature is 2700°F.

Iron $0.2089 \times 2640 \times 2000 = 1.103 \times 10^6$ Btu

Slag $0.3210 \times 2640 \times (3219.3 + 0.16\ C) = 2.728 + 135.5\ C$

3. Calcination of Limestone

The values used assume about half of the thermal requirement of decomposition of $CaCO_3$ is regained when CaO reacts with SiO_2, i.e. when the slag is formed.

Lime required $346.5 + .06C$

Heat required $\frac{(315 + .06C)}{56} \times 40{,}000 = 0.247 \times 10^6 + 42.8C$ Btu

4. Sensible heat in off-gas

The percentage CO and CO_2 to which the coke bed burns is of paramount importance in determining the coke rate, indeed the efficiency of the smelting process. An average to low efficiency for cupola operation has been selected.

Assume coke bed burns to 10% CO, 18.3% CO. Then one pound of C requires 7.81 lbs of air and produces 1.30 lbs CO_2, 1.51 lbs CO and 6.01 lbs N_2. Off-gas temperature 500^0F.

(a) Sensible heat in off-gas from burning of coke bed

CO_2	CO	N_2
$1.30C \times 440 \times 0.225$	$1.51C \times 440 \times 0.251$	$6.01C \times 440 \times 0.250$

(b) Sensible heat in off-gas from reduction reaction

CO_2	CO
$392 \times 440 \times 0.225$	$999.9 \times 440 \times 0.251$

(c) Sensible heat in off-gas from limestone decomposition

CO_2
$(272 + .047C) \times 440 \times 0.225$

Total, $a + b + c = .176 \times 10^6 + 966.1C$ Btu

Total, $1 + 2 + 3 + 4 = 7.360 \times 10^6 + 1139.6C$

Latent heat in off gas

1. from coke combustion 8.03×10^6 Btu
2. from reduction reaction 4.36×10^6 Btu

Note: the heat balance has not been extended to include the potential heat of the reduction carbon (char in briquet) as the coke rate is of primary interest. The heat potential of the 535.7 lbs C/ton Fe is 7.767×10^6 Btu of which 4.36×10^6 Btu or 56.1% appears in the off-gas.

Hot Blast

The following table indicates the coke rate reduction to be expected by using pre-heated blast air. Cupola operations often use hot blast up to $1000^{\circ}F$ (beyond which construction materials become expensive) while the blast furnace and low shaft furnace use stoves and temperatures of $2000^{\circ}F$ or more.

Sample Calculation, $1500^{\circ}F$ hot blast.

heat from coke + sensible heat in hot blast = heat requirements

C = 860

coke required: 956 lbs/NT Fe

TABLE 3

Hot Blast Temperature $^{\circ}F$	Coke Rate lbs/ton Fe
60	1357
500	1206
1000	1060
1500	956
2000	866

Ore Concentrate

Klymowsky[1] of the Mineral Sciences Laboratories of CANMET has obtained concentrates containing 44% Fe, 12% SiO_2. This reduces the slag load of the furnace from 3415 lbs to 1806 lbs and gives the following reduction in coke rates:

Blast Temp	Coke Rate, lbs
60°F	1357 → 1106
1500°F	956 → 779

The coke rate reduction appears significant, but beneficiation msut prove to be economically worthwhile.

In practice reducing the slag load may help to minimize operation problems such as flooding and aid carbon pickup of the metal.

Production Rate

Assume a wind rate of 350 cfm/sq ft of cupola area. One pound of carbon requires 102.1 of air and for cold blase carbon to be burnt per ton iron is 1221.5 lbs.

Production rate $\frac{350 \times 60 \times 24}{102 \times 1221.5} = 4.04$ tons Fe/day/sq ft

For 1500 °F hot blast

$$\frac{350 \times 60 \times 24}{102 \times 860} = 5.74 \text{ tons Fe/day/sq ft}$$